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PHYSICAL CHEMISTRY.—*Solubility in the system, KCNS-H_2O.*[1]

F. C. KRACEK, Geophysical Laboratory, Carnegie Institution of Washington.

In continuation of studies on solubilities in aqueous solutions at relatively elevated temperatures by the method of sealed tubes[2] it became desirable to re-design the apparatus for greater convenience and reliability. In testing out the new apparatus, the solubility of potassium thiocyanate in water was determined over the range extending from room temperature to its melting point. Reasons for selecting this salt were its relatively low melting point and rapid solubility. Unfortunately, the solubility has never been studied at temperatures above 25°C., so that no data exist for comparison at the higher temperatures. Furthermore, there are no thermal data on this compound available, with the sole exception of a calculation by P. W. Bridgman[3] of the heats of fusion and of a polymorphic transition, based upon P-V results at high pressures. The values given are 10.3 and 1.325 mkg/g, the extrapolated melting point and inversion point being given as 171.2° and 140°C. respectively.

EXPERIMENTAL

Materials. Reagent grade KCNS was further purified by recrystallization. The salt was dried at a temperature above the transition point, but below the melting point, in vacuum. No appreciable decomposition was noticed, except when the salt was heated above the melting point with free access of air. The melting point of the purified product was 176.8° ±0.1°C., and differed only a little from that of the dried commercial reagent. The transition temperature, 140.6° ±0.1°C., was unaffected by purification. The transition is remarkably prompt in either direction.

Apparatus. A well constructed air-bath thermostat was employed. In principle, this is a copper lined muffle furnace of rectangu-

[1] Received June 26, 1936.
[2] F. C. KRACEK, J. Phys. Chem. 35: 417, 947. 1931; J. Am. Chem. Soc. 53: 2609. 1931.
[3] P. W. BRIDGMAN, Proc. Am. Acad. Arts Sci. 51: 55. 1915.

lar cross-section, open at both ends, the muffle cross-section being 16.5×10 cm. The interior of the muffle is provided with an air propeller, and with a slowly revolving holder for the solubility tubes. The shafts carrying the propeller and the tube holder enter the muffle at the centers of the two side walls, being supported on graphite bearings (which need no lubrication) at the muffle ends, and on ball bearings at the outer ends. The end openings of the muffle are closed by removable glass doors which permit observation of the progress of the experiment. Three thicknesses of glass, providing two heat-insulating air spaces in series at each end, have been found to give adequate protection against disturbances of the temperature distribution.

The muffle, constructed of heavy *transite* board, is lined with copper plates *ca.* 6 mm thick. It is wound with approximately 16 ohms of No. 15 B. and S. gauge nichrome wire. The temperature attainable on 110 v. current is well above 600°C. The regulation of the temperature is provided for by a five-junction copper-constantan thermoelement operating a sensitive potentiometer controller. The hot junctions of the thermoelement are cemented to the muffle immediately outside the winding, but electrically insulated from it; the cold junctions are kept in melting ice. The rapid response of the thermoelement to changes in temperature of the winding, together with the rather large heat capacity of the muffle, and the high thermal conductivity of the heavy copper lining serves to provide satisfactory thermostatic operation. Exploration of the interior of the thermostat with a bare junction of a copper-constantan thermoelement showed that the temperature distribution is uniform to within 0.05°C. (with the air propeller in motion). The deviations from uniformity actually are momentary fluctuations, which for purposes of measurement are smoothed out by enclosing the measuring junction in a small bore copper tube. The temperatures as measured by the enclosed junction are found to be uniform, and constant to within ±0.01°C., which is sufficiently precise for the present purpose.

Procedure. Weighed quantities of purified KCNS and of pure water are sealed in Pyrex tubes of *ca.* 10 mm inside diameter, 12–15 cm long, and of 1 mm wall thickness. These tubes withstand a considerable internal pressure; in the present investigation the vapor pressures of the solutions are always low, and hence there was no danger from explosions. No corrosion of the tubes by the solutions could be detected.

The sealed tubes are rotated in the thermostat until all the crystals dissolve, as judged by visual observation. Owing to the destruction of nuclei on complete dissolution, the equilibrium can not be approached from above. This actually causes only a slight inconvenience in testing for the equilibrium temperature. If one or two crystals are present and the temperature is slightly lowered, then (a) if crystals begin to grow at once, the previous temperature was below the liquidus, while if (b) new crystals do not form, the temperature may still be above the liquidus, and more time must be given for the attainment of equilibrium, or (c) there may be a difficultly soluble impurity present. After complete dissolution, the undercooling in this system was usually 3° to 4° (Miers' supersolubility limit). It will be obvious that a solubility determination by this method consists of establishing, with as good approximation as may be necessary, the temperature at which the last crystal disappears in equilibrium with the solution. It is wholly analogous in principle to the quenching method so extensively used in this Laboratory for the study of equilibria in silicate systems.

The Experimental Results. Measurements of the solubility temperatures were made for compositions from 72.61 to 100 weight percent KCNS. The data obtained, together with a résumé of previously available determinations, are collected in Table I. The compositions are expressed in two ways: (1) in weight of salt per 100 g of water, which is the most suitable method for practical purposes, and (2) in mole percent (100 times the mole fraction) of salt, for theoretical purposes. In calculating the mole fractions an assumption must be made concerning the mole weights of the components in solution, or more exactly, concerning the *ratio* of the mole weights. The common practice is to assume the stoichiometric molecular weights. Other mole fractions may be computed, based on an *effective* mole weight ratio. The mole percent compositions listed in Table I are the stoichiometric values, based on 97.168 for KCNS and 18.0154 for water.

The solubility curves for KCNS in water can be expressed by means of empirical equations of the type

$$\log (100N_2) = a + \frac{b}{T} + c \log T + dT + \cdots \tag{1}$$

where N_2 is the mole fraction of KCNS, a, b, $c \cdots$ are empirical

TABLE I.—SOLUBILITY OF KCNS IN WATER

Expt.	g KCNS per 100 g Water	Mole % KCNS		Liquidus t°C.	Solid Phase
		Exptl.	Calcd.		
—	—	100.00	—	176.8	KCNS I
27	11961	95.69	95.56	170.7	"
5	9342	94.55	94.60	169.2	"
22	5773	91.46	91.47	164.5	"
21	4185.8	88.59	88.58	160.0	"
3	3599.6	86.97	86.97	157.4	"
2	3116.2	85.25	85.52	155.0	"
6	2471.1	82.08	82.23	149.4	"
7	2188.2	80.23	80.33	146.1	"
8	1957.7	78.40	78.50	142.7	"
9	1825.6	77.19	77.35	140.6	KCNS II
1	1476.1	73.24	73.24	133.9	"
10	1346.2	71.40	71.40	130.7	"
11	1150.2	68.08	68.00	124.6	"
12	956.6	63.94	63.90	116.8	"
13	802.9	59.82	59.80	108.4	"
14	673.6	55.53	55.53	99.0	"
15	526.9	49.42	49.45	84.2	"
20	455.90	45.81	45.83	74.5	"
16	408.45	43.09	43.12	66.7	"
19	358.60	39.93	39.94	57.0	"
17	317.05	37.02	36.92	47.3	"
18	265.10	32.95	32.73	32.6	"
(3)	239.0	30.70	30.70	25.0	"
(4)	217	28.7	29.41	20	"
(4)	177	24.7	24.52	0.0	"
(5)	101	15.8	17.64	−31.2	"

(3)—H. W. FOOTE, Z. physik. Chem. **46**: 79. 1903.
(4)—F. RÜDORFF, Ber. **2**: 68. 1869.
(5)—A. VASILIJEV, J. Russ. Phys. Chem. Soc. **42**: 423. 1910.

constants and T is the absolute temperature of the liquidus. The corresponding slopes are given by

$$\frac{d}{dT}\log(100N_2) = -\frac{b}{T^2} + 0.4343\frac{c}{T} + d + \cdots . \tag{2}$$

Because of the polymorphic inversion at 140.6°C., two equations must be used to express the solubility. The constants of the equations derived from the experimental data are as follows:

(a) For KCNS I, valid from the transition point (140.6°) to the melting point (176.8°),

$$a = -\ 20.71904$$
$$b = \ \ 892.459$$
$$c = \ \ \ 7.81532$$

(b) For KCNS II, valid at temperatures below the transition point,

$$a = \quad 31.85576$$
$$b = -957.918$$
$$c = -\ 12.27825$$
$$d = \quad 0.0108207$$

The (metastable) melting point of KCNS II, calculated from the (b) constants, is 171.6°C.

The computed values of the compositions are included in Table I for comparison with the experimental. The principal discrepancy between observed and calculated values is in the composition of the cryohydric point, for which Vasilijev determined a composition corresponding to 15.8 mole percent KCNS, whereas the calculated value is 17.64, at −31.2°C.

The results are graphically illustrated by Fig. 1.

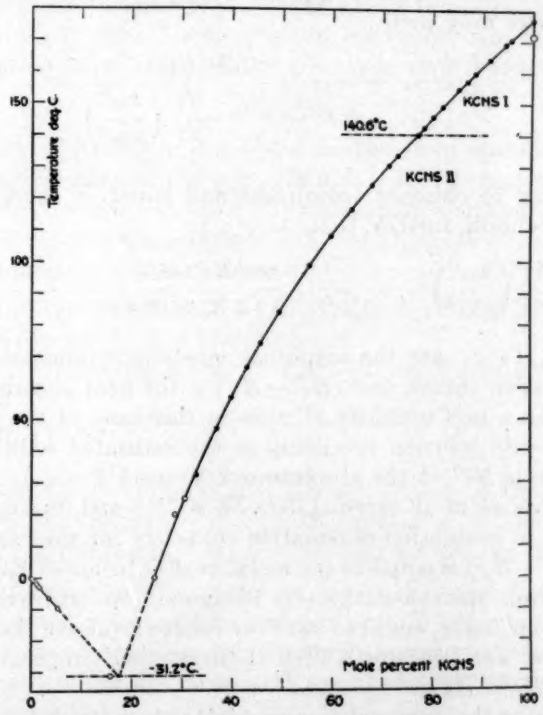

Fig. 1.—Equilibrium diagram for KCNS-H_2O. Black dots, present investigation. Open circles, previous data. Open circle at 171.6°, 100% KCNS represents the (metastable) melting point of KCNS II, extrapolated by use of equation (b).

DISCUSSION

Gibbs' theory of heterogeneous equilibria leads to the following general expression for the effect of temperature on the solubility in binary systems at constant pressure:

$$\frac{d}{dT}\ln N_1'' = \frac{N_1'(S_1''-S_1')+N_2'(S_2''-S_2')}{\frac{N_1'-N_1''}{1-N_1''}\left(\frac{\partial \mu_1''}{\partial \ln N_1''}\right)_{p,T}} \tag{3}$$

all the symbols having their usual significance, μ and S being (partial) specific or molal quantities, depending on whether N is in weight or mole fractions, respectively. The double accents refer to the solution, the single accents to the dissolving phase. The expression for the other component is symmetrical with (3) merely by interchange of subscripts. When the dissolving phase is the pure component 2, ($N_2' = 1$, $N_1' = 0$), we may write

$$\frac{d}{dT}\ln N_2'' = \frac{H_2''-H_2'}{RT^2\,\frac{1-N_2''}{1-N_2''}\cdot\frac{N_2''}{RT}\left(\frac{\partial \mu_2''}{\partial N_2''}\right)_{p,T}}. \tag{4}$$

Converting to common logarithms and equating expressions (2) and (4) we obtain, further, that

$$\frac{N_2''}{RT}\left(\frac{\partial \mu_2''}{\partial N_2''}\right)_{p,T} = \frac{H_2''-H_2'}{4.578(-b+0.4343\,cT+dT^2+\cdots)} \tag{5}$$

where b, c, $d \cdots$ are the empirical constants evaluated from the solubility curve values, and $(H_2''-H_2')$ is the heat absorbed by the system when a unit quantity (1 mole in this case) of the dissolving phase goes into solution reversibly in the saturated solution whose composition is N_2'' at the absolute temperature T.

In the absence of all thermal data on KCNS and its solutions, we are limited to evaluation of equation (5) solely for the case $N_2'' = 1$, where $(H_2''-H_2')$ is equal to the molal heat of fusion of KCNS. This we obtain from the calculations by Bridgman (op. cit.) whose values become, in cal/mole, equal to 2345 for KCNS I (above the inversion temperature) and 2647 for KCNS II (neglecting temperature coefficients of $(H_2''-H_2')$).

Substituting the appropriate numerical values for the constants in equation (5) from (a) and (b), and the corresponding numbers for the melting points of the two modifications (176.8° for KCNS I, and

171.6°, obtained by extrapolating (b) to 100 percent KCNS, for KCNS II), we obtain

$$\frac{N_2''}{RT}\left(\frac{\partial \mu_2''}{\partial N_2''}\right)_{p,T} = \frac{2345}{2961} = 0.795 \text{ for KCNS I,}$$

$$= \frac{2647}{3326} = 0.796 \text{ for KCNS II.}$$

The concordance of these two values is better than would be expected on the basis of the experimental data, for while the empirical equations (a) and (b) represent the data without a very pronounced trend of errors in either positive or negative direction, the slopes of the curves are much less accurately known, and it is probable that only an accidental compensation of errors leads to the computed close agreement between these two numbers; particularly so, since Bridgman himself states "It is especially to be noticed that the values [of ΔH and ΔE] given for the melting curve are only approximate; since no great effort was made to get these very accurately."

SUMMARY

Solubility of KCNS in water was studied from room temperature to the melting point of the salt (176.8°C.). KCNS undergoes a rapid polymorphic inversion at 140.6°C.; consequently, the solubility curve has a break at this temperature. The two branches of the curve can be represented by the equations:

(a) $\log (100N_2) = 892.459/T + 7.81532 \log T - 20.71904$
valid between 140.6° and 176.8°C., and
(b) $\log (100N_2) = -957.918/T - 12.27825 \log T + 0.0108207T + 31.85576$
valid below 140.6°C.

PALEOBOTANY.—*Plant distribution as a guide to age determination.*[1] RALPH W. CHANEY, Carnegie Institution of Washington, University of California. (Communicated by ROLAND W. BROWN.)

The determination of age of rock layers is one of the important objectives of the paleontologist and geologist. While many other considerations are of equal significance, it is clear that chronology—the establishment of the age or relative age of geologic formations—is a primary necessity.

Of the several lines of evidence used by the stratigrapher in deter-

[1] Received May 26, 1936.

mining the age of sedimentary rocks, there are two which may be of relatively little value to the student of Cenozoic paleobotany in western America: the vertical sequence of beds, and the stage of phylogenetic development of the fossils contained in them. A large number of occurrences of Cenozoic plants are in terrestrial deposits limited in areal distribution, and stratigraphically unrelated to underlying formations. There is comparatively little evidence of phylogenetic change among the angiosperms and conifers which make up the bulk of the plant record since the Cretaceous. It is therefore necessary for the paleobotanist to recognize and interpret another trend through later geologic time, a sequence involving changes in distribution.

There is general agreement among students of land life, both of the present and of the past, that changes in distribution are brought about by changes in living conditions. In other words, migrations do not result from any inherent tendency on the part of land plants, or of animals, to wander, but are the result of compulsion. Changes in topography, resulting from diastrophism, vulcanism and gradation, so alter environments as to compel the shifting of populations. Changes in climate, due to terrestrial or solar causes, force plants and animals to move over wide ranges of latitude. Alternatives to such migrations are extinction, or changes in habit or structure. All three of these results of dynamic physical control are apparent in the record of Cenozoic plant life in western America.

It may be assumed that so long as the earth has received the major part of its energy from the sun, and that so long as the continents have occupied their present positions, the factor of latitude has been of critical importance in determining the life of any region, and in establishing climatic differences between areas near or distant from the equator. The assumption of cosmopolitan floras and faunas on the land during the past tends to disregard the effects of difference in latitude upon life. Such an assumption is justified only when a considerable length of geologic time is involved, during which groups of plants and animals covered wide areas as a result of climatic change. The periods of the Cenozoic are so short relatively, and our information regarding their life is so relatively complete, that any literal application of the term "cosmopolitan" to fossil floras is highly misleading.

Evidence will shortly be presented for the conclusion that the plant life of any Cenozoic period in western America varied widely at different latitudes, and that altitude and also position with rela-

tion to topographic barriers had a differentiating effect. But it will first be appropriate to outline the general nature of the physical changes during Cenozoic time, from the Great Plains west to the Pacific.

During the opening period of this era, the Eocene, there was a wider transgression of the sea upon the continental borders than at any time since, although the invading seas were less extensive than during earlier eras. The absence of the present Coast Ranges, and the relatively incipient development of the Cascades and Sierra Nevada, resulted in the landward penetration of ocean climate almost to the Rockies. Only this range, which had been uplifted during the Cretaceous, served as a topographic and climatic barrier to the Great Plains at the east. Other factors, including increased solar energy, may have combined to make the climate of western America warmer and more humid than at present. In any case the relative submergence and low altitude of the area west of the Rockies during older Cenozoic time is at least a partial explanation of the subtropical climate indicated not only by the plants (1) but by the invertebrates and by the mammals (2). A more general circulation of air and of ocean currents, and possibly the cutting off of the Pacific Basin from the Arctic by the land connection between Siberia and Alaska, brought a climate to Oregon and California much like that in Mexico and Central America at the present time.

The nature of the older Cenozoic floras on the Pacific Coast has been described by the writer and his associates (3) and need not be considered in detail at this point. They are composed of broad-leafed evergreens, of which dicotyledons predominate, with subordinate elements of monocotyledons, conifers and ferns. Of the families represented, many are exclusively tropical in their present distribution. A majority of the genera are confined to low latitudes, or have their best development there. Such genera as *Allophylus*, *Calyptranthes*, *Cinnamomum*, *Cordia*, *Ficus*, *Lonchocarpus*, *Meliosma*, *Oreopanax*, *Persea*, *Sabalites* and *Tetracera* are represented by species whose modern equivalents occur in Mexico and Central America, or to a lesser extent in paleotropical regions. The characters of the leaves, especially their size, shape and texture, are suggestive of plants now living in the warmer parts of the world. The high tree-shrub ratio, and the relative abundance of vines, also suggest subtropical vegetation. Although the record is composed largely of leaf impressions, fossil wood and fruiting structures are gradually becoming available as a means of corroborating generic determinations.

Associated with these subtropical plants are other genera which are at present more wide-ranging in distribution, such as *Cornus*, *Magnolia*, *Platanus*, *Quercus*, *Ulmus* and *Viburnum*. Their occurrence with the more tropical types of plants has some parallel in the Mexican forests of today, and is suggestive of climatic conditions at lower to medium altitudes on the borders of the American tropics. Although quantitative estimates can be only approximate, the older Cenozoic vegetation of the western United States seems to require a climate having a mean annual temperature between 65 and 70°F., and a rainfall of not less than 70 inches a year.

The gradual withdrawal of the seas from the continental margins is indicated by the sequence from marine to terrestrial deposits in the Eocene and Oligocene systems of Oregon. The locally active upbuilding of mountain ranges, which reached its climax in the Pliocene, combined to bring about changes in climate which resulted in marked alterations in the vegetation. In favorable situations along the Pacific Coast, *Tetracera* and *Meliosma* lingered into the Middle Oligocene of northwestern California (4), and *Ficus*, *Oreopanax* and *Persea* survived into the Upper Miocene in central and southern California (5). But for the most part the subtropical elements of the Eocene forests were gradually eliminated from temperate latitudes by Middle Cenozoic time, due to reduced winter temperatures and lessened precipitation as imposed by continental climates on an emerging land mass.

Over a wide area extending from northern California to Colorado, north to Montana, and coastward to include most of Oregon and Washington, as well as parts of British Columbia, there developed in middle Cenozoic time a temperate forest in which *Sequoia*, of the coast redwood type, was a dominant element. Regularly occurring with it were the Tertiary equivalents of several common associates of the living redwood, of which the alder (*Alnus carpinoides*), tanoak (*Quercus consimilis*) and bay laurel (*Umbellularia oregonensis*) are the most common (6). In this redwood forest of the Miocene, there was also a group of broad-leafed deciduous trees which no longer live in western America, although they have survived in forests of somewhat similar types in the eastern United States and northeastern Asia. This group, including such genera as *Carpinus*, *Castanea*, *Fagus*, *Ostrya*, *Tilia* and *Ulmus*, has higher summer rainfall requirements than are afforded by the present climate of western America. It seems possible to assume that the conditions which now bring summer drouth on the Pacific Coast were not operative during the Miocene. Several genera occurring in the Miocene redwood forest

are now confined to Asia; *Cercidiphyllum* and *Ginkgo* are examples. Numerous specific resemblances, in such genera as *Castanea, Crataegus, Quercus, Rhus* and *Ulmus*, are close between trees of the American Miocene and those now living in China and Japan. Notwithstanding these exotic elements, the redwood forest of the middle Cenozoic had much the same general aspect as the modern forest of the California coast, as shown by the dominance in it of species corresponding to those most abundant today.

While *Sequoia* survived into the Upper Miocene forests of western America, it yielded its position of dominance to a group of genera which now occupy relatively exposed situations on the borders of the redwood forest. Black oak (*Quercus pseudo-lyrata*), live oaks (*Quercus simulata* and *traini*), maples (*Acer merriami* and *negundoides*), madroño (*Arbutus matthesii*), plane tree (*Platanus dissecta*), and such conifers as *Pseudotsuga, Abies* and *Pinus* make up the conspicuous trees of this younger forest (7). From the occurrence of the modern equivalents of these trees in a relatively cool and dry habitat, it has been concluded that further climatic changes had taken place since the Lower Miocene. A physical basis for such changes may be found in the increasing uplift of the Cascades, and the widespread vulcanism in this and adjacent regions during later Miocene time.

Less well known than the Miocene and Eocene floras, the vegetation of the Pliocene shows even more strikingly the effects of continued uplift. Over the wide area east of the Cascades, fossil plants are absent, so far as known, from the record. It is reasonable to suppose that the redwood was completely eliminated by the growing climatic barrier, and that other forests were limited in distribution. To the south, a modified redwood forest, with dominant oaks and *Pseudotsuga*, occupied the area adjacent to the ocean. But inland, where the effects of the sea were greatly lessened due to the building of mountain barriers, the vegetation is limited to poplar, willow, plane tree and other stream-border types, most of which still survive (8). A general trend from a warm, moist climate in the Eocene to a cool, dry climate in the Pliocene is therefore established by the fossil plant record. The physical conditions in the Pleistocene are also consistent with this thesis, but since floras of that age are limited in extent and contribute only confirmatory data to it, they will not be discussed here.

It seems desirable to emphasize at this point the rather obvious fact that most plant remains have been accumulated in sediments at low altitudes. There are occasional exceptions, but the great majority

of Cenozoic floras are made up largely of lowland species, with rarely any conspicuous element brought in from great distances. Widely transported material, in the form of wind-transported pollen grains or winged seeds, or of water-transported wood and cones, can commonly be recognized as being introduced from outside, because of its scarcity or worn condition. In most cases, the fossil record is made up of remains of plants which lived in close proximity to the areas of deposition along rivers, lakeshores or embayments. The sequence of Cenozoic floras is therefore a record limited almost entirely to the vegetation of the lowlands, and the climate and other physical conditions indicated by plant fossils are also those of areas near sea level.

In order to reconstruct an upland setting and the forest which occupied it, several assumptions may be made which are based on modern forest distribution. During the middle Cenozoic, when a redwood forest, commonly known as the Bridge Creek flora, occupied the lowlands of the John Day Basin and adjacent Oregon, it is reasonable to suppose that there was a forest on adjacent ridges and valley slopes which was less mesic in character. Such a forest, made up of life oaks, madroño and Douglas fir, is today characteristic of the borders of the redwood forest. This forest has its Cenozoic equivalent in the Mascall flora which followed the Bridge Creek flora in the John Day Basin of Oregon, and elsewhere in western America. It reflects an increasing uplift of the Cascades and the establishment of a relatively continental climate on their eastern and leeward side in later Miocene time.

In like manner, the Bridge Creek flora, recorded in sediments of late Oligocene or early Miocene age, may be assumed to have covered the more exposed habitats during Eocene and older Oligocene time, when the lowlands were occupied by a subtropical forest in which broad-leafed evergreens predominated. In the modern forests of Mexico and Central America, the lowland forests up to altitudes of approximately 4000 feet are essentially of the older Cenozoic type. They contain most of the genera which have been recorded from the Eocene and older Oligocene of the western United States, and are subtropical in aspect. On the higher slopes, and especially well-developed at altitudes around 7000 feet, the vegetation is temperate. A large number of the genera are among those listed from the middle Cenozoic, although *Sequoia* is missing and its place is taken by *Pinus*. Here, within a small area and separated only by differences in altitude, are two readily distinguishable forests whose fossil equivalents occur in the Eocene and in the Miocene of the western United States.

The possibility of a mixture of leaves from these two forests in contemporary deposits is slight, since the temperate forest is on upper slopes several miles distant from sites of deposition. Such leaves as are accumulating at the present time are of the subtropical, Eocene type. The upper forest, of a temperate and Miocene aspect, will doubtless be absent in the record of contemporary sediments in the same way that upland floras are unrepresented in the record of the Cenozoic.

A second method of determining the nature of upland vegetation during the past is to establish floristic relationships between two essentially contemporaneous floras at different altitudes and latitudes. Just as the modern forests of high altitudes have closely similar equivalents near sea level at higher latitudes, so the upland forests of the past may be reconstructed by a survey of contemporaneous fossil floras to the north. In such comparisons, the contemporaneity of the floras is not reflected by any close similarity in the plant assemblages. It might even be said that if a flora from Oregon was closely similar in composition to one from Alaska, the age of the two must be different. A separation in latitude of 20 degrees may be expected to have involved, in the past as at the present time, the development of plant assemblages of wholly distinctive composition. For the establishment of contemporaneity between such Eocene floras as the Kenai of Alaska and the Comstock of Oregon, it is necessary to depend upon other evidence of equivalence in age, such as the invertebrates, or the stratigraphic and structural relations of the associated beds.

When the Eocene floras of Alaska and of other high latitudes were first studied by Heer, it was assumed that they were of Miocene age because of their similarity to the Miocene vegetation of middle latitudes. Subsequently it was pointed out by Gardner (9) and others that the Eocene floras of high latitudes migrated southward to occupy middle latitudes during the Miocene period. This involved the concept of an holarctic center of distribution, an assumption which has been amply supported by evidence of fossil plants and mammals accumulated during the 57 years since Gardner made this statement. The close resemblance of the Kenai flora from the Eocene of Alaska to the Bridge Creek flora from the Upper Oligocene or Lower Miocene of Oregon fully supports the idea of a migration southward during the Cenozoic.

Since a temperate forest with redwood and broad-leafed deciduous trees was present at low altitudes in high latitudes during the Eocene,

it is reasonable to assume that a similar forest may have occupied higher altitudes in middle latitudes at this time. In other words, a situation similar to that described in the mountains of modern Mexico may be considered to have existed in Oregon and adjacent areas during the Eocene. A subtropical forest at low altitudes contributed leaves and other structures to the sedimentary record, where they have been preserved as fossils; but the temperate forest occupied altitudes so high that few if any of its representative elements entered the sedimentary record.

To many stratigraphers, the concept of a "Miocene" forest on the ridges or at high latitudes during the Eocene period is highly distasteful. Such a situation has given rise to the conclusion that Cenozoic plants are without value as time indicators. This is admitted as frequently the case, except as the latitude of the fossil plant occurrence is taken into consideration. But with an established climatic trend, based upon a known physical history of emergence and orogeny, the position of a Cenozoic flora with reference to the equator may indicate its position in the stratigraphic column as accurately as can the stage of evolution of a mammal or a mollusc.

It is not within the province of this paper to discuss the application of the idea of distribution in time to the invertebrate and vertebrate record.[2] The suggestion may be made, however, that it may be useful in some cases. Where a wide transgression like that of the early Paleozoic is involved, or the dispersal of such a genus as *Hipparion* over several continents, it seems possible that many of the disagreements among paleontologists regarding the time range of animals in the past may be solved by fuller knowledge of their centers of distribution and of their migration routes. When periods as long as those of the Paleozoic are involved, time designations as exact as those suggested for the Cenozoic may not be required, and the recognition of faunas in more general terms may be satisfactory. If it were sufficient to speak of a flora as of "Tertiary" age, the necessity would not exist for determining its changing geographic position from Eocene to Miocene time; it would be sufficient to designate the temperate redwood flora in these general terms, without regard for the fact that tens of millions of years were involved in the physical events which led to its southward migration from Alaska to Oregon. But such a characterization of this flora would involve not only a loose time con-

[2] See MATTHEW, W. D., *Climate and Evolution*, Ann. N. Y. Acad. Sci. 24: 171–318, 1915, for a critical statement of space relations involving vertebrates.

cept, but would leave many of the most critical aspects of earth history out of consideration.

With careful application, intercontinental correlations based on Cenozoic floras carry much weight if both occur at similar latitudes. But there are other factors which must be taken into consideration. One of these, the factor of altitude, is and has always been of great importance in determining the nature of vegetation. Its actual significance in paleobotanical studies is lessened by the fact that only a comparatively small proportion of upland plants permanently enter the fossil record. Another factor in the interpretation of the climate-distribution-age significance of a fossil flora is its position with relation to topographic and climatic barriers. The effect of the modern Cascade Range on the vegetation of eastern Oregon is striking; two wholly different plant associations occupy its western and eastern slopes. The uniformity of the middle Cenozoic redwood forest from western to eastern Oregon is interpreted as indicating that this barrier was not then in existence. Resemblances between the Eocene floras of Oregon, the Comstock in the western and the Clarno in the eastern part of the state, are so marked that the absence of any high intervening mountains during early Cenozoic time is indicated. Farther to the east, however, the Eocene floras of the Interior Province show the effects of the upbuilding of the Rocky Mountains during the Cretaceous period. Evidence of a climate less warm and moist than that bordering the Pacific may be recognized in the subordination of the subtropical element, and in the greater abundance and diversity of temperate genera. Such differences reflect divergent habitats rather than age discrepancies.

The practical value of such considerations as latitude and climatic barriers in age determination is illustrated by the recent study of a flora from Beaver County, Oklahoma (10). It is made up largely of plants related to those of the Miocene floras of the Rocky Mountain and Columbia Plateau provinces, and although redwood is missing, the usual procedure would have been to assign it to the Miocene. The association of a mammalian fauna, in which well-defined horses and beavers indicated Lower Pliocene age, raised objections to such an age reference. A study of the diatoms also indicated post-Miocene age. Here was a setting for another disagreement based upon divergent testimony of different lines of evidence.

It will be sufficient to state that an analysis of the Beaver County flora on the basis of its geographic occurrence also indicated its Lower

Pliocene age. The elimination of *Sequoia* and other mesic Miocene genera, and the increased abundance of stream-border trees such as poplar and hackberry, was in line with the occurrence of this flora on the High Plains east of the climatic barrier interposed by the Rocky Mountains. The position of the flora 500 miles south of the area in which the related Mascall flora is recorded, was consistent with its post-Miocene age, since a considerable time interval might be expected to have been involved in its migration southward. The concept of a climatic trend, resulting from continental uplift, and causing the movement of forests toward the equator during the Cenozoic, made possible the reference of a flora, which was "Miocene" in terms of its Oregon relationships, to the Pliocene period in Oklahoma.

This use of space relationships as a guide to floral age may be open to the criticism that the trend toward emergence in western America during the Cenozoic did not proceed continuously, and that there may have been reversals in the resultant climatic trend which would throw into error any conclusions based upon the physical significance of vegetation. To such criticism the reply may be made that conclusions based on the space-time relationship of floras in the Tertiary of western North America, so far as they have been made, are in accord with the evidence of fossil vertebrates and invertebrates, and with the stratigraphic sequence in so far as it is fully understood. If the climatic trend from the Clarno to the Bridge Creek and Mascall floras of the John Day Basin was not in accord with the sequence of these beds from older to middle Cenozoic, as established by Merriam 35 years ago (11), and if the evidence of the associated mammals was not consistent with the floral conclusions both as to age and environment, it is clear that conclusions based upon plant migrations would be open to doubt. The sequence of Tertiary floras, to which this climatic trend has been aligned, has however been verified in accord with all lines of evidence available in eastern Oregon. With this area as a point of departure, it is proving possible to judge the age of related floras on the basis of their geographic occurrence elsewhere. If inconsistencies are found when these studies overlap into areas where marine deposits are intercalated with those of the land, revision of criteria employed by both the paleobotanist and the invertebrate paleontologist may be necessary. It is only through the use of all possible lines of evidence that the true sequence of events may be determined and their full significance in terms of earth history understood.

It seems desirable to illustrate graphically the change in position of Cenozoic floras in western America as they are known from the data now available. Fig. 1 shows the distribution of the subtropical and temperate forest units during the early part of the era, at its middle, and in modern time. From an area extending from central California north into Washington, eastward into Montana, and south to New Mexico at the beginning of the Tertiary, the subtropical forest was shifted into southern California and the mountains of Mexico during the Miocene, and subsequently to the lower altitudes

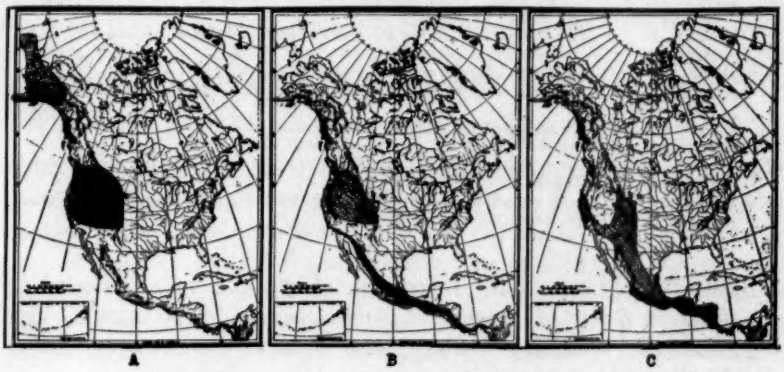

Fig. 1.—Showing distribution of subtropical and temperate forest units during the Cenozoic of western America. A, Eocene; B, Miocene; C, Recent. In all maps, closely spaced continuous lines indicate a subtropical, and broken lines a temperate forest.

of Mexico and Central America where it is now found. From Alaska, extending across into Siberia, in Eocene time, the temperate forest was shifted to middle latitudes during the Miocene. It is now broken up into various units, of which the dominant coast redwood forest has survived only along the coast from Oregon to central California, with elimination of many of the broad-leafed deciduous genera. Many genera of this temperate forest have survived also in the forests of the Cordillera, especially in the mountains of Mexico and Central America. A study of the distribution of this modern vegetation throws much light on the climatic history and the stratigraphic sequence of the Cenozoic rocks in western North America.

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ZOOLOGY.—*Notes on the Crustacea, chiefly Natantia, collected by Captain Robert A. Bartlett in Arctic Seas.*[1]

MARGARET E. VAN WINKLE, Wellesley College, and WALDO L. SCHMITT, U. S. National Museum.

Nearly every year for more than a decade Captain Bartlett has brought back a veritable zoological treasure trove to the United States National Museum. Some portions of his extensive collections have been reported upon by various specialists in this Journal, in the Proceedings of the National Museum, and in the Smithsonian Miscellaneous Collections. Here for the first time, however, is assembled a complete list of his decapod crustacea, together with some casual notes on a few other forms. The specimens listed were taken in each of the years 1924 to 1935, inclusive, with the exception of 1928 and 1934, when Captain Bartlett and his schooner, the *Morrissey*, were under exclusive contract to other parties.

Of particular interest are the collections made in Fox Channel, Fox Basin, and the Straits of Fury and Hecla north of the Melville Peninsula. The only decapod crustacea previously recorded from these waters were five in number, secured by the second Parry Expedition in the *Fury* and *Hecla*, for which the Straits were named, in the fall of 1822. These species were taken in nets off Igloolik

[1] Received April 2, 1936.

Island, the winter quarters of that year, where they were said to have been "found abundantly," or "taken in considerable numbers." These particular decapods are *Spirontocaris groenlandica*, *S. polaris*, *S. spinus*, *Sabinea septemcarinata*, and *Sclerocrangon boreas*.[2]

Captain Bartlett also obtained the same species at several stations in the same general neighborhood, with the exception of *Sabinea septemcarinata*. Indeed, two of the species, *Spirontocaris groenlandica* and *S. spina*, were caught in the entrance of the Straits at a point a little farther north than Igloolik Island, together with two other decapods not seen by the earlier expedition: *Spirontocaris phippsii* and *S. gaimardii*. *S. gaimardii belcheri* and *S. fabricii*, which were dredged by Captain Bartlett at several stations, had also been missed by the Parry Expedition, as had *Pagurus krøyeri*, which Captain Bartlett collected off Igloolik Island.

The bulk of the decapod material of the 1929, 1930, and 1931 expeditions, amounting to over a thousand specimens, was determined by Mrs. Van Winkle, of the Department of Zoology of Wellesley College. The second author undertook the balance of the material not otherwise credited. We are indebted to Dr. Mary J. Rathbun for naming the several species of brachyura, while the identifications of the amphipods cited in connection with the crustacea found in seal and codfish stomachs were furnished by Clarence R. Shoemaker, whose complete report upon the amphipods is reserved for a later date.

In order to add to our knowledge of the distribution of the species discussed in this paper, brief reference has also been made to crustaceans that were named for the Biological Board of Canada and which had been secured under its auspices during a series of biological and fisheries surveys carried on in Hudson Strait and Hudson Bay in the years 1927, 1928, and 1930.

For conciseness, the localities from which the Bartlett crustacea listed below were collected are referred to by number in the manner suggested by Austin H. Clark in his report upon the Bartlett echinoderms (this Journal 26: 294). For more ready reference, these lo-

[2] ROSS, JAMES CLARK. *Marine Invertebrate Animals*, in Appendix, Jour. . . . Third Voyage . . . Discovery . . . Northwest Passage . . . , p. 120, London, 1826; and in Appendix, Narrative . . . Second Voyage . . . Search . . . Northwest Passage . . . , pp. lxxxi–lxxxiv, London, 1835.

Nils von Hofsten, in his masterly treatment of the crustacea of Eisfjord, Spitzbergen (Kungl. Sven. Vet. Akad. Handl. 54 (No. 7). 1916), depicts the Ross finds, among others, on a series of charts showing the polar distribution of each of these five species, with the exception of *S. groenlandica*. On the distribution chart of this species the Igloolik record established by Ross appears to have been inadvertently omitted.

calities are arranged in five groups lettered A to E. Within their respective groups the localities have been arranged, so far as possible, in order of latitude from south to north, without regard to longitude or date.

Localities at which crustacea were dredged, unless otherwise indicated, are as follows:

A. LABRADOR COAST. 1. Saglek Bay, September 25, 1925. 2. Kamaktorvik Bay, 59° 31′ N., 63° 50′ W., July 12, 1929. 3. Coast of Labrador, August and September, 1925.

B. FOX CHANNEL AND FOX BASIN, BAFFIN LAND, AND MELVILLE PENINSULA. 4. Four to five miles east of Cape Dorchester, August 8, 1927, 25 fathoms. 5. West end of White Island, Comer Straits, August 10, 1933. 6. Hurd Channel, between Bushman Island west of Vansittart Island and Melville Peninsula, August 10, 1933. 7. Between two unnamed islands south of Cape Martineau, east of Duckett's Cove, August 19, 1933, 7–15 fathoms. 8. Three stations in Duckett's Cove, Hurd Channel, August 11–13, 1933, 1–14 fathoms. 9. Cove, north shore of Lyon Inlet, August 24, 1933, shore collecting, low tide. 10. Four stations in Fox Basin between 66° 30′ N.–66° 46′ N. and 79° 15′ W.–80° 07′ W., August 10–13, 1927, 32–37 fathoms. 11. Bight, Cape Penrhyn, August 31, 1933, 11 fathoms. 12. Fox Basin, 67° 45′ N., 79° 09′ W., August 24, 1927. 13. Center Fox Basin, August 24, 1927, 25 fathoms. 14. Between Ooglit Islands and Eskimo village at Pingitkalik, September 5, 1933. 15. Two short dredge hauls in entrance to Straits of Fury and Hecla, September 3, 1933, 20–30 fathoms.

C. BAFFIN BAY, ELLESMERE LAND, AND WEST GREENLAND. 16. Three stations, southeast end of Cobourg Island, 75° 40′ N., and between 78° 50′ W. and 78° 56′ W., August 3–4, 1935, 2½–18 fathoms, gravel-rocky bottom, surface temperature 38–39° F. 17. Two stations south end of Cobourg Island, 75° 40′ N., 78° 58′ W., August 4, 1935, 8–20 fathoms, very rocky bottom surface temperature 36°F. 18. Hudson Bay Company's Post, Ponds Inlet, Jones Sound, August 29, 1926, 10 fathoms. 19. Craig Harbour, Jones Sound, August 26, 1926, 7–20 fathoms. 20. Cape York, 76° 00′ N., August 21, 1926 and August 28, 1932, 7–15 fathoms. 21. Kerkotak, Salvo Island, Melville Bay, August 28, 1932. 22. Parker Snow Bay, 76° 07′ N., 68° 20′ W., July 22, 1926 and July 24, 1935, 5–12 fathoms, muddy bottom. 23. Off Dalrymple Rock, Wolstenholm Sound, July 22, 1926. 24. Saunders Island, Wolstenholm Sound, July 22, 1926, 10–12 fathoms. 25. Two stations, Karnah, Inglefield Gulf, August 14, 15, 1926, 5–20 fathoms. 26. Four stations off Northumberland Island, Whale Sound, August 15–17, 26, 1926, 7–30 fathoms. 27. Two stations off Herbert Island, Whale Sound, July 25, 1926, 4–25 fathoms. 28. Hackluyt Island, Whale Sound, 77° 26′ N., 72° 30′ W., July 30, 1935, 11–20 fathoms, bottom small stones, surface temperature 37°F. 29. Three stations, Murchison Sound, August 19–21, 1926, 17–20 fathoms. 30. Five miles south of Cape Chalon, July 27, 1932. 31. Cape Alexander, Smith Sound, August 26, 1932.

D. EAST COAST OF GREENLAND. 32. Four stations, Angmagssalik, August 30, 1930, August 27–29, 1931, 20 fathoms. 33. Off Cape Stosch, Hudson Land, 74° 04′ N., 17° 50′ W., July 30, 1931, 120 fathoms. 34. Between Clavering Island and Hornes Foreland, July 31, 1930. 35. Clavering

Fiord, August 2, 1930. 36. Pendulum Island, July 20, 1930. 37. Bight Shannon Island, July 29, 1930.

E. BERING SEA AND ALASKA. 38. One and a half miles southeast of Cape Cheerful, Unalaska, August 4, 1924, from stomach of fish taken in 3 fathoms. 39. About 15 miles north of Big Diomede Island, June 14, 1924. 40. Twenty-two miles off Shishmaref Inlet, June 27, 1924, 18 fathoms, ship stationary in ice. 41. Thirty miles off Devils Mountain, June 20, 1924, 16–18 fathoms, mud bottom. 42. Two stations, mouth of Kotzebue Sound, July 10, 1924, 10–17 fathoms, mud bottom, ship drifting in ice.

SPECIES COLLECTED

Pandalus borealis Krøyer. D and C. Taken twice by Captain Bartlett from the stomach of codfish at Angmagssalik, east Greenland, August 27, 1931, remains of two specimens; and at Laxebugt, Disko Island, 69° 19′ 14″ N., 54° 14′ W., fragments of one specimen.

Pandalus goniurus Stimpson. E 39, 41, 42.

Spirontocaris groenlandica (J. C. Fabricius). B 7, 15. C 16, 17, 20, 23, 25, 26, 27, 29, 31. D 32. At Angmagssalik, east Greenland, this species was also found in the stomach of a cod, August 27, 1931.

The Biological Board of Canada had specimens obtained along the western shore of Hudson Bay, north of Churchill in 19 and 42 fathoms, off Mansel Island in 75 fathoms; in Hudson Strait at Nottingham Island and Sugluk Creek: and at Port Burwell, Ungava from cod stomachs.

Spirontocaris polaris (Sabine). A 2, 3. B 4, 5, 7, 8, 9, 10, 11, 13, 14. C 16–23, 25, 26, 27, 29, 30, 31. D 32, 33, 35, 36. Also found in cod stomachs, Angmagssalik, east Greenland, August 27, 1931. In one lot of specimens (B 7) there were no lateral spinules on the epimera of the fourth abdominal somite of one specimen, while another had a spinule on the left side only.

The Biological Board of Canada had received specimens from the southern part of Hudson Bay, 57° 19′ N., 85° 32′ W., from 52 to 54 fathoms; from Hudson Strait at Nottingham Island and Sugluk Creek; and from Wakeham Bay and Port Burwell, Ungava, both dredged and from cod stomachs.

Spirontocaris microceros Krøyer. A 1. Two specimens of good size were collected by Captain Bartlett from Saglek Bay, Labrador, September 1, 1925. The larger, 42 mm in length, had four rostral teeth, two on the carapace and two on the rostrum proper; the rostrum reached to the middle of the cornea and fell a little short of the first segment of the antennular peduncle. The smaller specimen, about 34 mm in length, was very typical of the species; its rostral teeth were five in number, two on the carapace and three on the rostrum proper; the rostrum was about as long as the eye, but a little short of the first segment of the antennular peduncle.

The Biological Board of Canada had a specimen of this species from a cod stomach from Port Burwell, Ungava, and two others determined as *S. zebra* Leim from the same source. Stephensen,[3] with Miss Rathbun,[4] believes that these two species are probably identical. In his paper Stephensen lists five localities on the southwest coast of Greenland where undoubted *S. microceros* has been obtained. Leim[5] records *S. zebra* from three localities in New Bruns-

[3] STEPHENSON, K. *Crustacea Decapoda, Godthaab Expedition.* Meddel. Grønland, **80** (No. 1): 81. 1935.

[4] RATHBUN, M. J. *Decapoda.* Canadian Atlantic Fauna, **10** m: 12. 1929.

[5] LEIM, A. H. *A new species of Spirontocaris with notes on other species from the Atlantic Coast.* Trans. Royal Canadian Instit. XIII (No. 4): 137. 1921.

wick and one in Nova Scotia, but makes no mention of *S. microceros*. Miss Rathbun contributes another locality for *S. microceros*: Misaine Bank, off Cape Breton Island, 45° 19′ N., 58° 51′ 15″ W., 45 fathoms.

Spirontocaris phippsii (Krøyer) (= *Hippolyte turgida* Krøyer). A 2. B 5, 6, 13, 14, 15. C 20–31. D 32. In occasional specimens of *S. phippsii* the lower or smaller of the two supra-orbital spines may fail to develop.

This species has also been taken by the Biological Board of Canada at Nottingham Island in Hudson Strait; and at Wakeham Bay and Port Burwell, Ungava, at the latter place from cod stomachs.

Spirontocaris spina (Sowerby). A 2, 3. B 7, 10, 14, 15. C 17, 21, 23, 25, 26, 27, 29, 30, 31. D 32. E 42. Also found in stomach of cod, Angmagssalik, east Greenland, August 27, 1931.

The Biological Board of Canada has taken this species in Hudson Bay, just south of Mansel Island in 88 fathoms; in Hudson Strait at Sugluk Creek; and in Wakeham Bay and Port Burwell, Ungava; at the last named locality, however, only from cod stomachs.

Spirontocaris fabricii (Krøyer). A 2, 3. B 11, 14. C 22, 23, 24, 25. One large ovigerous female about 65 mm long out of a lot of five specimens from Parker Snow Bay (C 22) carries an adventitious supraorbital spine on the right orbital margin. This abnormality is of some interest, as the identity of the specimen is otherwise beyond question.

This species, like *Chionoecetes opilio*, mentioned below, is found in Arctic Alaska, the Bering Sea, and Siberia, as well as from Casco Bay, Maine, to west Greenland. Miss Rathbun[6] has already reported *S. fabricii* from Port Burwell, Ungava, and the east side of Hudson Bay, where the Biological Board of Canada secured a specimen in 1930 north of Churchill in 30 fathoms; additional specimens were obtained from Wakeham Bay and from cod stomachs from Port Burwell, Ungava.

Spirontocaris gaimardii (Milne Edwards). A 1, 2, 3. B 4, 6, 8, 10–15. C 16, 22, 25–28, 31. D 32, 34. E 39, 40, 42. Also found in cod stomachs at Angmagssalik, east Greenland, August 27, 1931.

The Biological Board of Canada has taken *S. gaimardii* at two stations along the southwestern shore of Hudson Bay in from 20 to 38 fathoms; and again from cod stomachs at Port Burwell, Ungava.

Spirontocaris gaimardii belcheri (Bell). A 2. B 7, 10, 13. C 20, 23, 25, 27, 29. D 32. Also found in cod stomachs at Angmagssalik, east Greenland, August 27, 1931.

Von Hofsten (*op. cit.*, p. 29) does not believe that the subspecies of *S. gaimardii* can be sustained as distinct entities, and gives his distribution records as for the species proper.

Spirontocaris stoneyi Rathbun. E 39. The single specimen that Captain Bartlett dredged north of Big Diomede Island, Bering Strait, constitutes the third known record for the species. Originally described from the Bering Sea,[7] it has since been found at Shoal Tickle, southeast of Nain, Labrador.

Crago dalli (Rathbun). E 39.

Sabinae septemcarinata (Sabine). A 3. A single specimen was obtained from the stomach of a Ringed Seal secured off the Labrador coast in 1925. I cannot explain its absence from the dredge hauls made by Captain Bart-

[6] RATHBUN, M. J. *Decapod Crustaceans*. Canadian Arctic Expedition, 7 (Pt. A): 13A. 1919.

[7] RATHBUN, M. J. *Decapod Crustaceans*. Harriman Alaska Expedition, X: 103. 1904.

lett, for it was taken by the second Parry Expedition off Igloolik Island near the Straits of Fury and Hecla and occurs on both coasts of Greenland. It is a more or less circumpolar species.

In Hudson Bay it was taken by the Biological Board of Canada at nine stations in the southeastern central part of the Bay in depths ranging from 30 to 87 fathoms.

Sclerocrangon boreas (Phipps). B 6, 8, 10, 13. C 16, 18, 20, 22, 23, 25, 26, 27, 29, 30, 31. D 32, 33, 35, 37. E 39, 42.

Captain Bartlett found **Sclerocrangon boreas** in cod stomachs as well as in his dredgings from Angmagssalik, east Greenland, August 27, 1931.

This shrimp grows to good size and is one of the principal articles of food of the square-flipper seal, **Phoca barbata.** One to several dozen could be recognized from among the stomach contents of four different specimens of this seal. The two largest Sclerocrangons taken from these seal stomachs were 4½ and 5 inches long. One of these square-flipper seals was captured in the Straits of Fury and Hecla, another in Lyon Inlet, and two out in Fox Basin at approximately 66° 12′ N., 78° 59′ W. The depth of the water in this vicinity is 34 fathoms.

Sclerocrangon boreas, says von Hofsten (*op. cit.*, p. 80), is a panarctic form, also penetrating the boreal region in favorable localities. It prefers very cold waters and ground overgrown with algae. The matted, fibrous contents of the stomachs of two seals from Fox Basin, which contained numerous *S. boreas* substantiates this.

In Hudson Bay the Biological Board of Canada obtained this crustacean at four stations more or less in the same latitude across the middle of the Bay at depths ranging from 30 to 72 fathoms; specimens were also collected at Nottingham Island, Hudson Strait; and at Port Burwell, Ungava from a cod stomach.

Sclerocrangon ferox (Sars). D 33. A truly high arctic form, found only in waters of very low, usually negative, temperature and at depths of ninety fathoms or more. We find but a single specimen in Captain Bartlett's collection, from 120 fathoms, near Cape Stosch, Hudson Land, east Greenland, 74° 04′ N., 17° 50′ W., July 30, 1931. This is the third specimen of the species ever to come to the National Museum and the first we have had from the western hemisphere.

Argis lar (Owen). E 39, 40, 41, 42. With this species Stephensen unites the next, *A. dentata* Rathbun. Though known from Greenland to Nova Scotia, and from the Bering Sea to British Columbia and east to Siberia, in Captain Bartlett's collection it is represented in hauls made only between Bering Strait and Kotzebue Sound in 1924.

Argis dentata (Rathbun). A 2. C 20, 22, 29, 31. D 32. Also found in cod stomach from Angmagssalik, east Greenland, August 27, 1931.

The Biological Board of Canada has specimens of this species from eight stations well scattered throughout Hudson Bay, with depths ranging from 30 to 80 fathoms; and both free swimming and from cod stomachs from Port Burwell, Ungava.

Pagurus krøyeri Stimpson. B 15. A single specimen taken off Igloolik Island at the entrance to the Straits of Fury and Hecla.

As European workers still merge this species with *P. pubescens* Krøyer, it is impossible to define the distribution of either species. In the National Museum there is an extensive series of *P. krøyeri* from along the east coast of America as far south as Virginia, 37° 19′ 45″ N., 74° 26′ 06″ W., from 120 fathoms; several Labrador localities are represented: off Narak, Nain, Port

Manvers, Cape Mugford, and Hebron, 7–60 fathoms; and Greenland: Godhavn Harbor, Disko Island, and Hare Island, 70° 20′ N., 56° W., 90 fathoms. Further, there are specimens from the Firth of Clyde, 10–15 fathoms, and from Varanger Fiord, East Finmark. For the specimens of true *P. pubescens* in the collection of the Museum, the southern limit is off Cape Hatteras, 35° 42′ 00″ N., 74° 54′ 30″ W., 43 fathoms, while the northern limit is Egg Harbor, Labrador, 7 fathoms.

The Biological Board of Canada got a specimen from each of two Hudson Bay stations on the west side of the Bay north of Churchill, in depths of 30 and 63 fathoms; and another specimen from a cod capture at Port Burwell, Ungava.

Pagurus trigonocheirus Stimpson. E 39, 40, 41, 42.

Pagurus capillatus (Benedict). E 42.

Pagurus splendescens Owen. E 39, 40, 41, 42.

Pinnixa occidentalis Rathbun. E 38. A single specimen from about the northern limit for this species, from the stomach of a fish caught 1½ miles S.E. of Cape Cheerful, Unalaska.

Chionoecetes opilio (O. Fabricius). E 40, 41. In its distribution, *C. opilio* is like *Spirontocaris fabricii*, occurring in the Pacific boreal and arctic regions, as well as on the northeast coast of America and west Greenland, but not in east Greenland. Unlike *S. fabricii*, its presence in Fox Basin cannot be established. Captain Bartlett's three specimens of this species are from the arctic coast of Alaska.

Hyas araneus (Linn.). A 3.

Hyas coarctatus alutaceus Brandt. A 3. C. E 39, 40, 41, 42. Captain Bartlett got one specimen of this species along the Labrador coast in 1925; fragments of 10 small individuals from a cod caught at Laxebugt, Disko Island, Greenland, in 1935; and 10 at four localities in the Bering Sea and Alaska in 1924.

The Biological Board of Canada obtained this crab in James Bay; at Fort Churchill and Churchill River; and at six dredge stations in the eastern and northwestern parts of Hudson Bay from depths of 19 to 82 fathoms; in Hudson Strait from Charles Island, Nottingham Island, Sugluk Creek, and Eric Cove; and at Cape Wolstenholme, Wakeham Bay, and Port Burwell, Ungava.

CRUSTACEA IDENTIFIED FROM THE STOMACH CONTENTS OF WHALES, SEALS, AND FISH

Sperm whale. Decapoda: *Chionoecetes opilio* (O. Fabricius).

Finback whale. Euphausiacea: *Thysanoessa inermis* (Krøyer), *T. raschii* (M. Sars).

Sulphur-bottom whale. Euphausiacea: *Thysanoessa raschii* (M. Sars). Amphipoda: *Themisto compressa* forma *bispinosa* Boeck.

Ringed or Floe-rat seal. Decapoda: *Sabinea septemcarinata* (Sabine). Euphausiacea: *Thysanoessa inermis* (Krøyer), *T. raschii* (M. Sars). Mysidacea: *Mysis oculata* (O. Fabricius). Amphipoda: *Themisto libellula* (Mandt), *Gammarus locusta* (L.).

Bearded or Square-flipper seal. Decapoda: *Sclerocrangon boreas* (Phipps). Isopoda: *Arcturus baffini* (Sabine).

Harp seal. Euphausiacea: *Thysanoessa inermis* (Krøyer). Amphipoda: *Themisto libellula* (Mandt).

Unidentified seal. Decapoda: *Spirontocaris gaimardii belcheri* (Bell). Mysidacea: *Mysis oculata* (O. Fabricius).

Codfish. Decapoda: *Pandalus borealis* Krøyer, *Spirontocaris groenlandica* (J. C. Fabricius), *S. polaris* (Sabine), *S. spina* (Sowerby), *S. gaimardii* (Milne Edwards), *S. gaimardii belcheri* (Bell), *Sclerocrangon boreas* (Phipps), *Argis dentata* (Rathbun), *Hyas coarctatus alutaceus* Brandt. Amphipoda: *Themisto libellula* (Mandt), *Anonyx nugax* (Phipps), *Pseudolibrotes nanseni* Sars, *Gammarus locusta* (L.), *Gammaracanthus loricatus* (Sabine).
Unidentified fish. Decapoda: *Pinnixa occidentalis* Rathbun.

ZOOLOGY.—*The histology of nemic esophagi. VI. The esophagus of members of the Chromadorida.*[1] B. G. CHITWOOD, Bureau of Animal Industry, and M. B. CHITWOOD.

This paper is the sixth of a series (Chitwood and Chitwood, 1934–1936) dealing with the structure of esophagi in representatives of various groups of nematodes. Previous papers in the series have covered representatives of the Rhabdiasidae, Strongylidae, Metastrongylidae, Heterakidae, Rhabditidae and Anguillulinidae. The present paper covers representatives of the order Chromadorida, namely: Plectidae, Camacolaimidae, Axonolaimidae, Comesomatidae, Cyatholaimidae, Tripyloididae, Desmodoridae, Chromadoridae, Monhysteridae, Linhomoeidae, and Siphonolaimidae. In representatives of the Chromadorida as in the other aphasmidian order, Enoplida, absolute identifications of nerve cell, radial and marginal nuclei are often not possible, as there is too little distinction between the characters of these 3 types of nuclei, and the cell bodies of "nerve cells" are seldom observable. However, the distribution of nuclei is sufficiently similar in the various genera for homologies to be ascertained. In the following text, the authors have identified nuclear types to the best of their abilities. In some instances it has been possible to determine cytologically the identity of a given nucleus, while in other cases the position indicated that the nucleus in question was homologous to one definitely identified in another form although they might differ cytologically in some respects. Future papers will include representatives of the orders Enoplida (Enoplata, Dorylaimata, and Dioctophymata) and Spirurida (Camallanata and Spirurata).

The data given in this paper are, for the most part, presented in tabular form (Figs. 3, 5, 10) and in illustrations, since the essay form of presentation would result in extended descriptions requiring much more space than the present form. The text calls attention to the major features given in the tables and illustrations, and presents some data not immediately obvious in the latter. Previous papers in

[1] Received June 22, 1936.

this series supply extended descriptions of other forms, sufficient to orient the reader of the present paper.

PLECTUS GRANULOSUS (Plectidae) Figs. 1, 2, 3

The esophagus of *Plectus* resembles in a general way that of *Rhabditis*, as does the mouth cavity; it consists of an anterior cylindrical part, the corpus, connected with a posterior swelling or bulb by an indistinctly set off isthmus. The lumen of the esophagus is similar to that of *Rhabditis* in that in the precorpus it terminates marginally in well developed "tubes" (Fig. 1, B), while in the remainder of the esophagus the lumen is simple, i.e., without particular modification, except in the bulb where it is hexalobate at the valve.

The precorpus contains 29 nuclei (Fig. 1, A-E) as follows: One group of 3 bilobed or 6 marginal nuclei, (m_{1a-b}–m_{3a-b}); 3 groups of 6 radial nuclei each (r_{1-6}, r_{7-12}, and r_{13-18}); and 2 groups of nerve cell nuclei (n_{1-3} and n_{5-6}). The marginal nuclear pairs, m_{1a-b} etc., may or may not be connected in such a way as to represent lobes of a single nucleus rather than individual nuclei; however, it is not possible to determine this on the basis of present material. A similar appearance is given by the marginal nuclei in *Rhabditis*, in which case the lobes were found to be joined anteriorly (Chitwood and Chitwood, 1936).

The postcorpus contains 26 nuclei (Fig. 1, F-L); 6 marginal nuclei (m_{4a-b}–m_{6a-b}), similar to those of the margins of the precorpus, 6 radial nuclei (r_{19-24}), and 14 nerve cell nuclei ($n_{4,7-19}$). The isthmus is too indistinct to be recognized as a unit. The most posterior nerve cell nuclei of the postcorpus might be considered as belonging to the isthmus.

The prevalvar region of the bulb contains 14 nuclei (Fig. 1, O–P), of which 6 are marginal nuclei (m_{7a-b}–m_{9a-b}), 6 radial nuclei (r_{25-30}), and 2 nerve cell nuclei (n_{20-21}).

The postvalvar region of the bulb contains 24 nuclei as follows (Fig. 1, Q–S); 6 marginal nuclei or nuclear lobes (m_{10a-b}–m_{12a-b}), 6 radial nuclei in 2 groups (r_{13-33}, r_{34-36}), 9 nerve cell nuclei (n_{22-30}), and 3 gland cell nuclei (g_{1-3}). The marginal nuclear pairs of the postvalvar region of the bulb appear in all probability to represent lobes rather than individual nuclei. In the series illustrated (Fig. 3) m_{11} is not double; n_{22-24} were not observed.

The orifices of the esophageal glands were not determined with absolute certainty. The dorsal gland appears to open into the lumen at the base of the stoma, while the subventrals appear to open at or near the level of n_{17-19}.

The esophago-intestinal valve of *Plectus* is extremely well developed (Fig. 2, A–C) and consists of 23 nuclei. (Some of these nuclei are probably intestinal—compare Figs. 2, B–C and 2, I). The valve is laterally elongated and rather flat.

Two other representatives of the same subfamily, very closely related to *Plectus*, were studied, these being *Chronogaster gracilis* and *Wilsonema bacil-*

livorus, in both of which the nuclei of the esophagus appear to be similar in number and distribution to those of *Plectus*.

ANONCHUS MIRABILIS (Plectidae) Figs. 2, D–F; 3

The esophagus of *Anonchus mirabilis* is cylindrical in the adult stage, but corpus, isthmus and pseudobulb are faintly recognizable in larval stages.

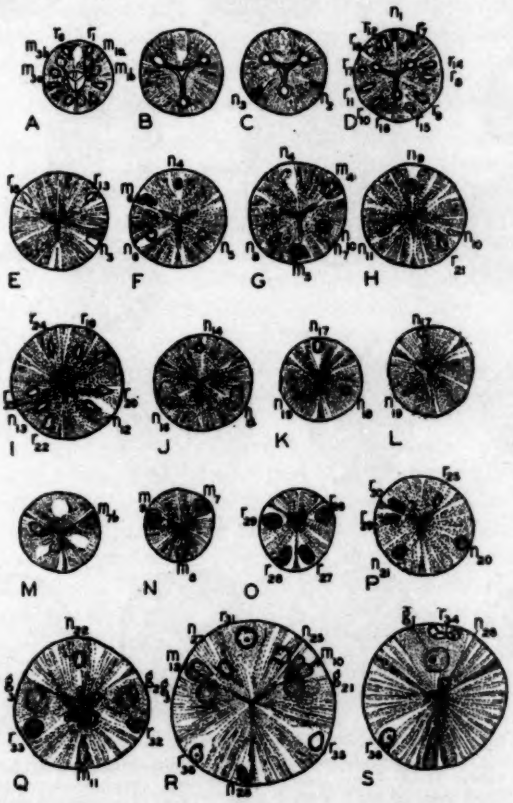

Fig. 1.—*Plectus granulosus*. A–F, precorpus; F–L, postcorpus; M–P, prevalvar region; Q–S, postvalvar region (See Fig. 2, B, for n_{29-30}).

The lumen is simple and triradiate, without marginal "tubes" (Fig. 2, E). The most striking pecularity of the esophagus is the presence of large chromidial bodies in the marginal regions (Fig. 2, D).

The nuclear number and distribution is nearly identical with that of *Plectus granulosus*, the following differences being noted: n_{20-21} and n_{23-24}

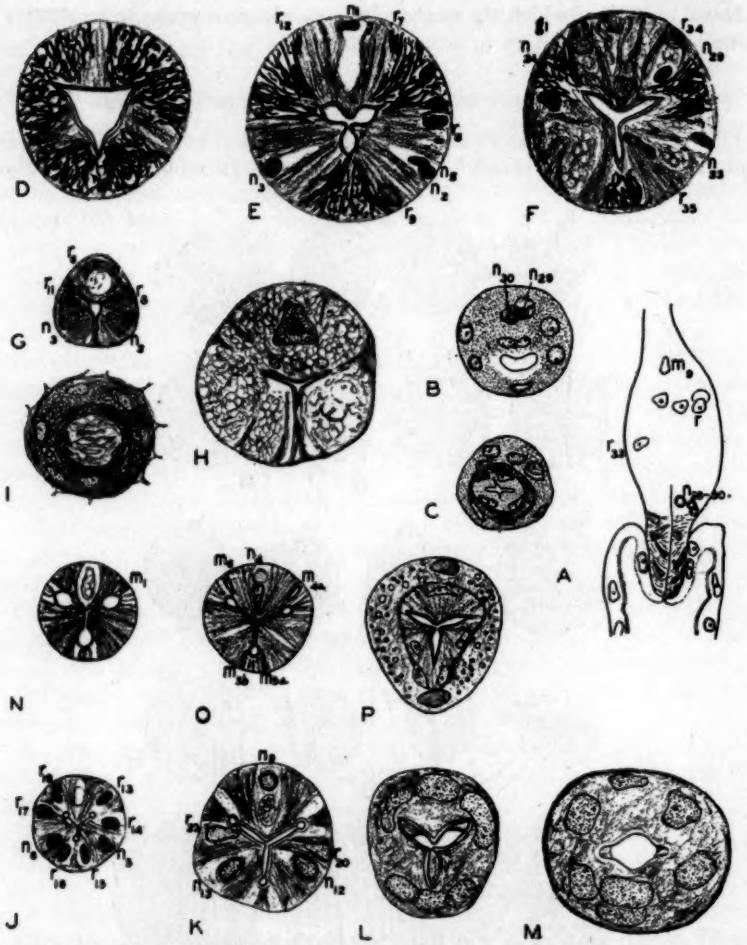

Fig. 2.—A–C, *Plectus granulosus*. A, Longitudinal section through bulb and esophago-intestinal valve; B–C, Cross sections, through esophago-intestinal valve (also includes very small part of bulb with n_{29-30}). D–F, *Anonchus mirabilis*. D, corpus at base of stoma; E, corpus somewhat further posterior; F, bulbar region. G–I, *Camacolaimus prytherchi*. G, corpus; H, base of bulbar region showing g, and n_{25-30}; I, esophago-intestinal valve. J, *Axonolaimus spinosus*, corpus. K–M, *Sabatieria vulgaris* K, corpus; L–M, esophago-intestinal valve. N–P, *Paracanthonchus* sp. N, anterior part of corpus O, corpus somewhat more posterior, P. esophago-intestinal valve.

are in the dorsal parts of their respective sectors; n_{25} and n_{28} have not always been found; n_{27} has not been observed; the marginals have been inconsistently observed owing to the confusion caused by the marginal chromidial bodies.

The marginal nuclei are very faint and nothing definite can be said about them. The gland cell nuclei differ from the other nuclei in that several small nucleoli are present instead of a single large one (see Fig. 2, F). The esophageal glands are very large and there is a vesicle near the orifice of each gland. The dorsal gland opens into the lumen of the esophagus anterior to the level of the first radial group, while the subventrals open anterior to the level of n_{17-19}.

The esophago-intestinal valve is similar to that of *Plectus* but the dorso-ventral form is more pronounced. Eleven large nuclei and possibly 4 smaller ones were observed in this structure.

CAMACOLAIMUS PRYTHERCHI (Camacolaimidae) Figs. 2, 3

The esophagus of this species is cylindroid, slightly constricted at the nerve ring, and gradually enlarged posteriorly. The lumen is normally closed, simple or triradiate, and minute marginal "tubes" are present only in the anterior part of the esophagus (Fig. 2, G). There is a total of 81 nuclei, the same number as in *Plectus* if the marginals are considered as lobed nuclei rather than double nuclei. The following differences in nuclear distribution in this species, as compared with *Plectus granulosus*, have been noted: N_{23} and n_{24} are in the ventral or marginal regions of their respective sectors; n_{26} is anterior to m_{11}; the fifth group of radials is subdivisible into 2 groups, $r_{25,\ 27,\ \text{and}\ 28}$ being posterior to $r_{30,\ 26,\ \text{and}\ 29}$ respectively; $r_{14\ \text{and}\ 22}$ were not always observed.

The esophageal glands are much more highly developed in *Camacolaimus* than in *Plectus* and occupy the greater part of the bulbar region (Fig. 2, H). The dorsal esophageal gland appears to open into the lumen slightly anterior to m_{1-3}, while the subventrals open near the level of n_{15-16}.

The esophago-intestinal valve (Fig. 2, I) is elongated, dorso-ventrally flattened, and contains 11 nuclei (only 8 shown in figure).

The rudimentary stoma is surrounded by esophageal tissue and contains a dorsal tooth which is apparently not connected with the dorsal esophageal gland.

APHANOLAIMUS sp. (Camacolaimidae) Fig. 3

The esophagus of *Aphanolaimus* is narrow, gradually enlarged posteriorly and without visible modified regions; the stoma is completely rudimentary and esophageal tissue extends to the anterior extremity. The esophageal lumen is simple, as is also the esophageal lining.

The first, second and fourth groups of marginal nuclei are simple, while the third group is lobed as in *Plectus*. There are a total of 80 nuclei, corresponding to those of *Plectus* with the following exceptions, m_{7bx} and m_{9ax} were inconsistently observed as lobes of m_{7b} and m_{9a}, respectively; n_{27} is posterior to g_1; $r_{25\ \text{and}\ 28}$ are nearly marginal in position; n_{23-24} were not observed but 1 nucleus, x_1, marginal in position, and in the right subventral sector, may correspond to n_{24}.

The esophago-intestinal valve is similar to that of *Camacolaimus*.

The esophageal glands are similar to those of *Camacolaimus* except that the dorsal gland nucleus is near the left side of the dorsal sector.

AXONOLAIMUS SPINOSUS (Axonolaimidae) Figs. 2, J; 3

The esophagus of *Axonolaimus* is clavate, relatively short, and muscular throughout. This form is very close to *Plectus* in the character of the stoma and also in the presence of well developed marginal "tubes" in the corpus (Fig. 2, J). The nuclear distribution of the corpus is closer to that of *Plectus* than to any of the forms previously mentioned. The first marginal group appears to consist of 6 separate and distinct nuclei (m_{1a-1b}–m_{3a-3b}); this is followed by the first 3 radial groups ($r_{1-6,7-12,13-18}$) in series. The second marginal group appears to be somewhat variable. In the series illustrated it consists of 7 separate nuclei, 4 ($m_{4a1,4a2}$ and $m_{6a1,6a2}$) being present in the dorsal sector, 2 (m_{4b} and m_{5a}) in the left subventral sector, and 1 (m_{5b}) in the right subventral sector. The fourth group of radial nuclei appears to consist of 6 or 8 nuclei (r_{19-24}) with the ventral nucleus in each subventral sector sometimes doubled ($r_{21a,21b}$ and $r_{22a,22b}$). The nerve cells of the corpus agree in number and position with those of *Plectus*.

The nuclei of the bulbar region are difficult to identify, and the labelling given in Fig. 3 is to some extent arbitrary. The nuclei labelled c_{1-3} are large and bilobed; $n_{23\text{ and }24}$ also appear to be bilobed in some instances.

The dorsal esophageal gland orifice is situated just anterior to the first group of marginal nuclei, while the orifices of the subventral glands appear to be near the level of n_{18-19}.

The esophago-intestinal valve is well developed but not so elongated as in *Plectus*; it is distinctly triradiate anteriorly and rather circular posteriorly, containing 10 to 11 nuclei. It is very similar to the valve of *Subatieria vulgaris*.

For purposes of comparison with *Plectus*, the total number of nuclei or nuclear lobes in the corpus is 58 (55 in *Plectus*) and in the bulbar region 35, 38 or 40 (38 in *Plectus*).

DORYLAIMOPSIS METATYPICUS (Comesomatidae) Fig. 5

The stoma and esophagus of *Dorylaimopsis* are closest, among the forms thus far studied, to those of *Axonolaimus*. The marginal "tubes" are well developed, and there is a very slight thickening of the cuticular lining extending throughout the corpus. The first and second marginal groups appear to consist of 3 bilobed nuclei. Data regarding the radial nuclei are not entirely satisfactory, but there appear to be 22 or 24 radial nuclei (in 4 groups) in the corpus, r_7 and r_{12} of *Axonolaimus* being the ones sometimes absent. The nerve cell nuclei (n_{1-19}) of the corpus agree with those of *Axonolaimus*. The marginal nuclei of the bulbar region (m_{7-9} and m_{10-12}) are simple. As in *Axonolaimus*, r_{27} and r_{28} are posterior to r_{26} and r_{29}, but r_{25} and r_{30} are at the

level of r_{27} and r_{28}. The last group of radials presents the unusual arrangement of r_{32} and r_{35}, being anterior to the level of r_{33} and r_{34} which are in turn anterior to r_{31} and r_{36}; the closest counterpart of this grouping is seen in *Theristus*. The nerve cells of the bulbar region correspond in number to those of *Plectus*, n_{20-21} being just posterior to r_{27-28} and slightly ventral to the mid-

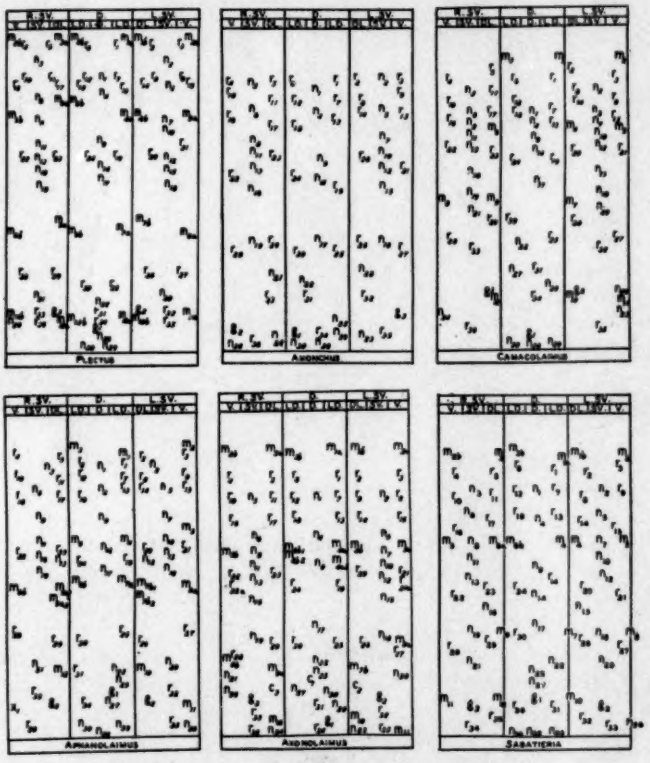

Fig. 3.—Table of nuclear distribution.

sector region; n_{23-24} are subventral, posterior to r_{33-34}; $n_{22,25,30}$ are distributed approximately as in *Plectus;* g_{1-3} are all in the center of their sectors between the levels of r_{33-34} and r_{31} and r_{36}. The esophageal glands of *Dorylaimopsis* are highly developed; the dorsal gland orifice is at the base of the stoma, and the subventral gland orifices are at the level of n_{18-19}. The glandular tissue is relatively much greater in this form than in *Axonolaimus* or *Plectus* but not as great as *Camacolaimus*. The esophago-intestinal valve is small and dorsoventrally flattened, and contains 12 nuclei.

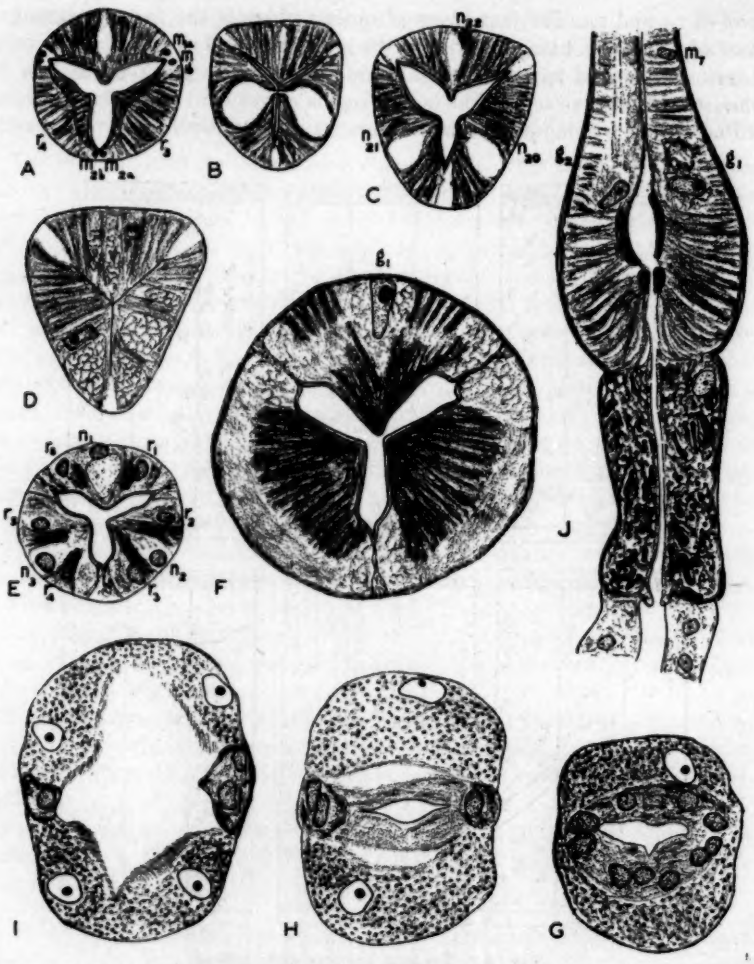

Fig. 4.—A–D, *Theristus setosus*. E–I, *Terschellingia pontica*. E, corpus; F, bulbar region; G–I, serial sections through esophago-intestinal valve. J, *Desmolaimus zeelandicus* v. *americanus*, longitudinal section through bulb, and esophago-intestinal valve.

SABATIERIA VULGARIS (Comasomatidae) Figs. 2, K–M; 3

The esophagus of *Sabatieria* is like the esophagi of *Axonolaimus* and *Dorylaimopsis* in that well developed marginal "tubes" are present. In the gross morphology, shortness and relatively great development of the esophageal glands is more nearly like *Dorylaimopsis* than *Axonolaimus*. Un-

like both of the mentioned forms, the posterior part of the stoma is collapsed and completely surrounded by well developed esophageal tissue.

The nuclei of the esophagus agree substantially with *Dorylaimopsis* both in number and distribution (See Figs. 3, 5). The lumen of the esophago-intestinal valve is triradiate anteriorly, laterally elongated posteriorly; 12 nuclei are present in the valve.

The dorsal esophageal gland has its orifice near the level of m_{1-3}, i.e., posterior to the base of the collapsed stoma. The subventral glands have their orifices at the level of n_{17}, i.e., the level of the nerve ring.

PARACANTHONCHUS sp. (Cyatholaimidae) Fig. 2, N–P

The esophagus of *Cyatholaimus* presents several interesting modifications. The stoma is completely surrounded by esophageal tissue, and a dorsal tooth projects into the anterior part of the lumen. This tooth probably corresponds to one of the three present in *Dorylaimopsis*. There is no evidence of its connection with the dorsal esophageal gland which appears to have its orifice at the base of the stomatal region. The slightly clavate esophagus presents no external peculiarities except that the lumen (Fig. 2, N) is rather unusual, the general appearance being that of an axonolaimoid or plectoid form (Figs. 1, 2, J) in which the termini of the margins have become converging after having once been tubular; this is best visualized by comparison of the illustrations.

Both the marginal and radial nuclei are practically marginal in position; the marginal nuclei of the corpus are double. Since our series are incomplete, no attempt to give nuclear distribution will be made. However, the general impression is very similar to that given by *Dorylaimopsis*.

The esophago-intestinal valve is short, markedly triradiate (Fig. 2, P) and consists of 8 nuclei which definitely belong to the valve, and 5 additional nuclei which also may belong to that structure; there are also 4 nuclei dorsal to the esophagus in a mass which apparently connects with the body wall.

BATHYLAIMUS sp. (Tripyloididae)

The esophagus of *Bathylaimus* is cylindrical, and surrounds the conoid stoma. The lumen is nearly of a simple triradiate character; the esophageal radii extend nearly to the external surfaces in *Theristus* but the margins are very faintly rounded showing a similarity to *Sabatieria*. The general outline of the esophageal cross-section is subtriangular, not unlike that of *Theristus* (Fig. 4, A) instead of nearly round as in the forms previously described. The position and form of the radial and marginal nuclei are also more like that of *Theristus* than of *Cyatholaimus*. The radial muscles are diffuse in attachment to the lining. Incompleteness of our series prevents us from giving further data on the structure of this form. The esophago-intestinal valve is triradiate.

THERISTUS SETOSUS (Monhysteridae) Figs. 4, A–D; 5

The esophagus of *Theristus* is cylindrical, its lumen simple, and the lining unmodified. The dorsal esophageal gland opens near the base of the conoid stoma, while the subventral esophageal glands open near the level of n_{15-16}. The radial and marginal nuclei differ greatly in size as well as in position (Fig. 4, A). When clearly observed, the first 2 groups of marginal nuclei are

Fig. 5.—Table of nuclear distribution.

double, while the fourth is not doubled. The third group of radial nuclei consists of only 3 instead of 6 present in other forms. The esophago-intestinal valve is partially triradiate (anteriorly), but at the junction with the intestine it is definitely flattened dorsoventrally, practically identical with *Terschellingia* (Fig. 4, H); it contains 23 nuclei.

MONHYSTERA CAMBARI (Monhysteridae) Fig. 5

The esophagus of *Monhystera cambari* is similar to that of *Theristus*, with the following exceptions. The representatives of the fourth group of radial nuclei (r_{18-21}) are all at the same level or nearly so; n_{23-24} are ventrally sub-

marginal just posterior to the level of r_{30-31}; r_{29-32} and r_{30-31} are at levels in reverse of the levels at which they are, respectively, in *Theristus*; all of the marginals are simple except m_2 (not doubled). The esophago-intestinal valve is similar to that of *Theristus* and *Terschellingia*; 19 nuclei were observed.

TRIPYLIUM CARCINICOLUM V. CALKINSI (Linhomoeidae) Figs. 5, 6

The esophagus of *Tripylium* is cylindroid; anteriorly it surrounds the prismoidal stoma; posteriorly it is connected with the intestine through an enlargement commonly termed the "bulb" though this structure is not a

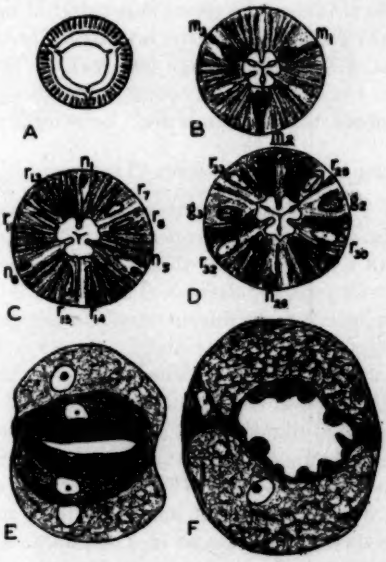

Fig. 6.—*Tripylium carcinicolum* v. *calkinsi*. A, stomatal region; B–C, corpus; D, bulbar region; E–F, esophago-intestinal valve.

part of the esophagus. The lumen is modified throughout due to the thickened cuticular attachment points of the lining (Fig. 6, C). This type of lumen appears to be derived from a plectoid or rhabditoid type in which there has been a disappearance of the marginal tubes and a development of attachment points for the radial muscles; such a phenomenon occurs in the development of forms such as *Oesophagostomum*.

The nuclei are distributed as in *Theristus*, with the following exceptions. The marginal nuclei are not doubled and are directly marginal in position (Fig. 6, B); r_{22} and r_{27} are at the same level as r_{23} and r_{26}; r_{28} and r_{33} are posterior to r_{29} and r_{32}; n_{23-24} are ventral submarginal and immediately anterior to the level of n_{28-30}, n_{26} being just anterior to n_{23-24}.

The esophago-intestinal valve is dorsoventrally flattened (Fig. 6, E–F), but some explanation regarding this region is necessary. Baylis (1915) and

Cobb (1920) have considered the swelling as an esophageal "bulb," and actually this structure is formed by the esophago-intestinal valve and the intestine. At least 12 nuclei are ectodermal in origin; the external tissue forming the "bulbar" enlargement, probably endodermal in origin, contains 4 nuclei. The cytology of the latter is identical with that of the intestinal cells following it.

In the related linhomoeid, *Desmolaimus*, there is a cylindrical elongated structure (Fig. 4, J) between the esophagus and intestine; the definite ectodermal valve tissue makes up only a small part of the esophago-intestinal cylinder. However, in this case the tissue is peculiar in being basophilic and differing both from the esophagus and the intestine. The esophagus is similar in all respects to that of *Tripylium* except for a well developed chromodoroid swelling at its base. On the basis of comparison with the postesophageal structure of linhomoeids, this structure must be considered as a new organ.

TERSCHELLINGIA PONTICA (Linhomoeidae) Figs. 4, E–I; 5

The esophagus of *Terschillingia* consists of a cylindrical corpus, following a rudimentary stoma, and a well developed bulb; the latter is actually a part of the esophagus, not a homologue of the so-called bulb of *Tripylium* but a homologue of the bulb of *Desmolaimus*. The lumen is subdistally dilated (Fig. 4E, F); the musculature is concentrated, but no cuticular thickenings of the lining are present. The nuclear distribution (Fig. 5) is rather similar to that of *Tripylium*, *Theristus*, and *Monhystera*, but only three groups of radial nuclei were observed in the corpus; n_{23-24} and n_{26} were not observed. The dorsal gland orifice is slightly anterior to the level of the first group of marginal nuclei (m_{1-3}) while the subventral gland orifices are at the level of n_{15-16}. The esophago-intestinal valve (Fig. 4, G–I) is very strongly dorsoventrally compressed and contains at least 19 nuclei, probably more. It is surrounded by intestinal epithelium as in *Tripylium*.

SIPHONOLAIMUS CONICUS (Siphonolaimidae) Fig. 5

Siphonolaimus is a peculiar form concerning the stoma and esophagus of which there has been much discussion. Being limited to a study of a single series of sections, the writers present the results of their study of this form with as little interpretation as possible. The minute stoma seems to be in the form of a stomatostyle surrounded by muscular tissue which consists of 6 strands passing posteriad and closely applied posteriorly to the anterior end of the esophagus, then passing to the body wall where they are inserted sublaterally. The stomatostyle overlies the anterior end of the esophagus in which 3 distinct cavities are present. Whether or not these cavities represent the 3 esophageal glands is not known; only the dorsal cavity is traceable posteriorly past the isthmus.

In the corpus a total of 37 nuclei were observed, 16 corresponding to n_{1-16} of other forms, while the remainder are marginal and radial nuclei. The lat-

ter probably correspond to m_{1-3}, r_{1-6}, r_{7-12} and r_{19-24} other forms, i.e., the third radial group and second marginal group are apparently absent. The bulbar region contains 32 nuclei. The esophago-intestinal valve is dorsoventrally flattened and contains 6 nuclei which definitely belong to the valve.

MONOPOSTHIA HEXALATA (Desmodoridae) Figs. 7, 10

The esophagus of *Monoposthia* is, in general, typical of the Chromodoroidea and Desmodoroidea. The prismoidal stoma (Fig. 7, A) is surrounded by esophageal tissue which protrudes anteriorly into the lumen in

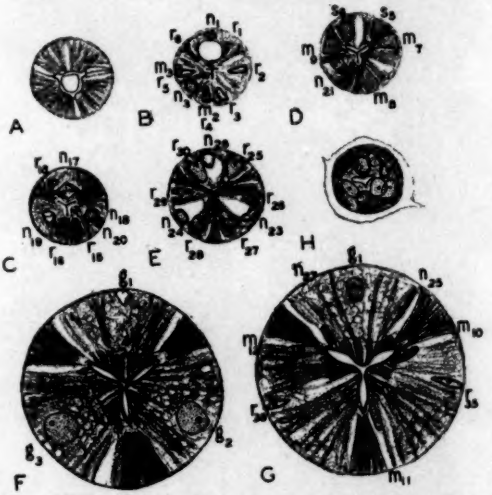

Fig. 7.—*Monoposthia hexalata*. A–C, corpus; A, in stomatal region; B, just posterior to orifice of dorsal gland; C, near base; D–G, bulbar region; H, esophago-intestinal valve.

the form of a large dorsal tooth. The post-stomatal region of the esophagus consists of a cylindroid corpus gradually enlarged posteriorly and joined directly to the short thick bulb. The lumen of the corpus is very minute, showing but faint indications of terminal "tubes."

The corpus contains 55 nuclei as follows: 2 groups of 3 marginal nuclei (m_{1-3} and m_{4-6}); 4 groups of 6 radial nuclei ($r_{1-6,\ 7-12,\ 13-24}$); 19 nuclei (n_{1-19}) presumably of nerve cells; and 4 nuclei (s_{1-4}) possibly of nerve cells.

The bulb contains 40 nuclei as follows: 2 groups of 3 marginal nuclei (m_{7-9}, m_{10-12}); 12 radial nuclei in 3 groups (r_{25-30}, r_{31-33}, r_{34-36}); 3 gland nuclei (g_{1-3}); 10 presumptive nerve cells (n_{22-30}); and 8 possible nerve cells (s_{5-12}); and 1 nucleus of uncertain type (x_1).

The dorsal esophageal gland appears to open into the lumen of the esophagus near the level of n_1, while the subventrals appear to open near the anterior end of the bulb (around the level of n_{20-21}).

The esophago-intestinal valve is short, more or less triradiate, and contains about 12–15 nuclei (Fig. 7, H).

Metachromadora, a closely related form of the same family, has an esophagus similar in a general way to that of Monoposthia but the esophageal lining has well developed thickenings for the attachment of radial muscles, particularly well developed in the bulbar region.

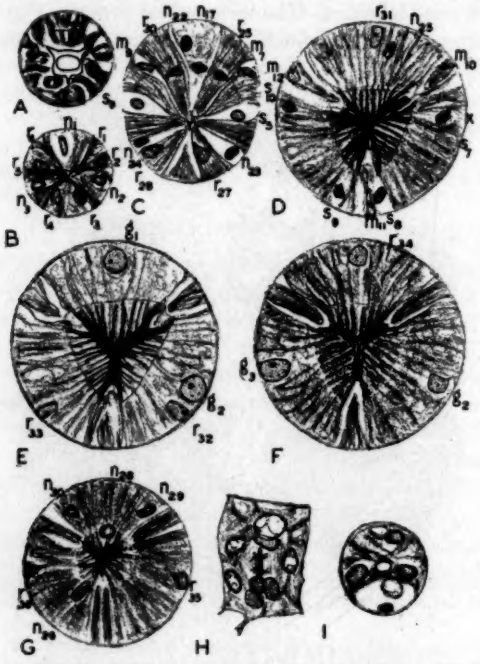

Fig. 8.—*Ethmolaimus rivaliensis*. A, stomatal region; B, corpus; C–G, bulbar region; H–I, esophago-intestinal valve.

ETHMOLAIMUS RIVALIENSIS (Chromadoridae) Figs. 8, 10

This form is nearly identical in esophageal structure with *Monoposthia*. The stoma, lumen and gross morphology are similar. The nuclei of the corpus (55) appear to be similar in character and distribution, there being 6 marginal nuclei, 24 radial nuclei, and 4 questionable (s_{1-4}). Most of the nuclei (total 39) of the bulb likewise correspond to those of *Monoposthia*, with the following exceptions. s_{5-6} were not recognized but 2 additional nuclei were sometimes observed in the left subdorsal sector.

The esophago-intestinal valve is short, dorsoventrally elongated, and contains 13 nuclei.

CHROMADORA sp. (Chromadoridae) Figs. 9, D–K; 10

The esophagus of this form is similar to that of *Ethmolaimus* and of *Monoposthia*, with the following exceptions: Grossly the stomatal region is not set off from the remainder of the esophagus and the bulbar region is relatively much shorter and smaller; the distinction between marginal and radial regions is more marked; 6 additional nuclei were observed in the corpus (x_{1-6}); the third group of radial nuclei is double (hence 6); s_5, s_6, n_{22a}

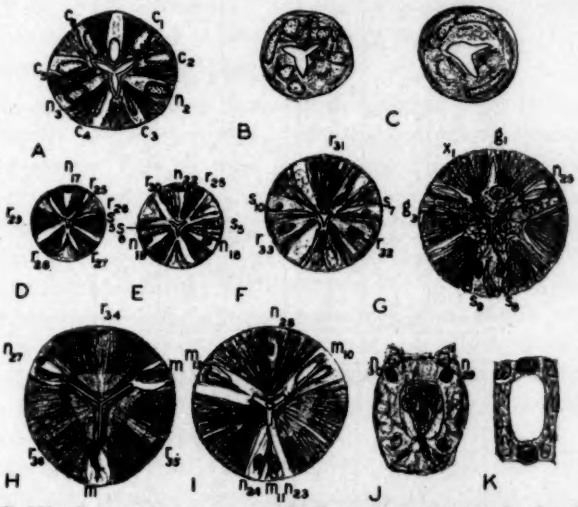

Fig. 9.—A–C, *Microlaimus* sp. A, corpus; B–C, esophago-intestinal valve. D–K, *Chromadora* sp. D–I, serial sections through bulbar region; J–K, esophago-intestinal valve.

(of *Monoposthia*) were not observed; additional nucleus (x_7) right laterodorsal was observed near the level of g_1, otherwise the nuclei in the bulbar region are as in *Monoposthia*. The esophago-intestinal valve is dorsoventrally elongated, consisting of 12 nuclei. *Chromadora* exhibits a pair of subdorsal pigment spots which consist of masses of brown granules in the subdorsal marginal and submarginal areas of the esophagus just posterior to the stomatal region; no special cells were observed in association with the spots.

MICROLAIMUS sp. (Microlaimidae) Figs. 9, A–C; 10

The esophagus of Microlaimus resembles that of Chromadora more closely than any other of the forms studied. The subtriangular stoma is surrounded by esophageal tissue, the corpus is cylindrical, the bulbar region quite enlarged and the esophago-intestinal valve elongated. The lumen (Fig. 9, A) is without marginal tubes and the lining without thickened cuticular attachment points though the radial fibers are highly concentrated. The number of nuclei and their disposition is clearly most like *Monoposthia*, *Ethmolaimus*

and *Chromadora* (compare Figs. 7–10). However, in addition to the nuclei s_{1-10}, there is a group of 6 nuclei (c_{1-6}) apparently resulting from further division of the second radial group (r_{7-12}). The elongate form of the esophagointestinal valve grossly recalls the form of that structure in *Camacolaimus*, *Plectus*, or *Terschellingia*, but the cross section (Fig. 9, B–C) clearly indicates other relationships since it is plainly triradiate. It contains 11 nuclei.

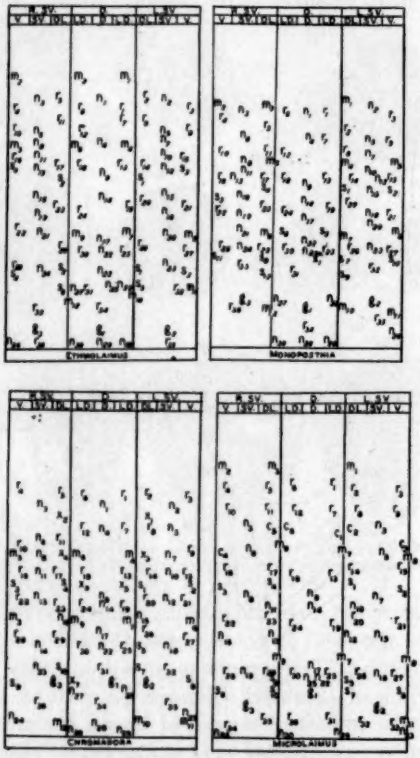

Fig. 10.—Table of nuclear distribution.

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